Good morning. My name is Billy Tiller, founder of Grower Information Services Cooperative (GiSC). I am honored to be given the opportunity to talk to you about the state of ag data innovation today. My interests in this subject are personal; not only as the founder of GiSC, but also as a 4th generation farmer operating a 6,400-acre family farm in the High Plains of West Texas, producing cotton, grain sorghum, and sunflowers. As a farmer who has long realized the value of digital data systems – from the efficiencies of digital information capture and data exchange to the productivity potential of data analysis – I began to see the almost endless use cases for technology applications for my operation and my partners' operations in the food & fiber supply chain. In 2010, I began a conversation with my longtime friend and associate Monty Edwards, a large crop insurance agent with deep generational roots in agriculture, about how digital technologies could improve our businesses, communications with partners, and ultimately, our quality of life.

Through those conversations and additional investigation, we determined a unified, digital agri-information system with certain capabilities was needed to truly "digitally transform" farm operation information. Ideally, this information system would be capable of: 1) capturing and collecting significant farm operation data, 2) organizing and normalizing that data into logical data sets; and 3) sharing information, both from farmers to their trusted third parties and from those third parties back to farmers (with farmers in control of that sharing). At the time GiSC was formed in late 2012, the then commercially available technology existed to create an information system with these capabilities. However, at that time no such system, or similar solution, had been adopted by growers on any scale.

Today, in 2017, that continues to remain the case. Farmers' data related to their operations are stored in "data silos." Some of that data are stored in various "clouds", uploaded from technology applications purchased by famers or provided to them by various vendors. Other data are stored locally in thumb drives and hard drives. Yet even more data are recorded on paper, stored on farmers' pickup truck dashboards and farm office desks and filing cabinets.

GiSC sprang from the conclusion that the "disconnect" between current information collection and distribution practices and the digital possibilities was (and continues to be) at least as much a business organizational problem as a technology problem and involves the relative value of farmers' data. Unlike the data captured and communicated on typical technology/information platforms for consumers, such as social media platforms, farm operation data is, in essence, intellectual property – the farmer's trade secrets and "know-how." Farmers are hesitant (and rightfully so) to entrust that data with third parties in which those farmers have no vested interest.

Bridging this disconnect, for us, was to turn to an organizational form US growers have turned to for generations to solve shared problems: farmer cooperatives. Granted, the vision of GiSC, as a data cooperative, was a unique idea back in 2012 and, as far as I am aware, remains a one-of-a-kind

organization to this day. GiSC, as a technology/business platform, provides its farmer-members what no other platform can: real control over their Intellectual Property, their farm operation data.

By offering a secure data platform service (an integrated system of technology tools and applications) to its members, GiSC can provide the obvious benefits of digitalization to an industry that finds itself outpaced by most other industries in information technology adoption, while at the same time protecting farmers' interest in their data. A cooperative is owned by its members. Farmers, by owning the service that provides the digital platform to capture, collect, and store operational data, are afforded two valuable and distinct advantages:

- Control – Through the data governance provided by GiSC (its members and board of directors) and GiSC's primary value proposition: growers own all the data that originates on their operations or from their operations' activities.
- Value – GiSC is uniquely positioned to return value back to its farmer-members for their willingness to include their data in the Coop's digital platform, whether in the form of operational benchmarks and insights, advanced data analytics, and/or member patronage.

GiSC Today: At a Glance

GiSC has grown from those initial conversations in 2010 and its formation in 2012 to a nation-wide cooperative, with 1,400 forward looking farmer-members from 41 states. GiSC has developed a vast network of loyal supporters who share its vision. As an example, GiSC has built a strong working relationship with the Agricultural Data Coalition (ADC), a coalition of research universities, prominent grower organizations and associations, equipment manufacturers, and regional input/service providers. These entities came together in an effort to help farmers better control and manage their data and to promote innovation in the industry. GiSC and ADC continue to work together to identify synergies and target opportunities for cooperation in areas in which the two organizations share mutually aligned values.

The fact is many things have changed for GiSC since its inception to today. However, GiSC's three key objectives, the Coop's cornerstone and foundation, remain the same.

1) Bring attention to farmers' vested interest in their farm operation data and continue, with like-minded individuals and organizations, to establish the precedent that growers should (and must) own and control the data related to their agricultural operations.
2) Offer its farmer-members (and future members) a secure digital platform that functions as a central repository for all of the grower's operational data, while providing governance of how that data is treated through the cooperative model.
3) Return value back to its farmer-members as the digital platform grows in both users and information.

GiSC has faced a myriad of challenges raising the capital necessary to architect a robust digital platform, especially given the premise that ownership of that platform resides with its members. In spite of those challenges, GiSC stands on the precipice of bringing its vision to reality. GiSC is working with Ag Simplicity, LLC to integrate GiSC's licensed Authenticated Information Exchange platform with the information technology applications Ag Simplicity is currently developing. The integrated system, to be

offered as AgSimp™ through GiSC to its members, provides key components for a robust, comprehensive digital platform solution. These components include:

- A simple on-farm data collection solution that provides real-time operational data capture with little effort or time from farm operators;
- A secure, cloud based Farm Information Management System with the capabilities to:
    - Interface with other technology tools and services utilized in a farm operation, collecting the data generated from those tools and services;
    - Synchronize all data sources for the most complete picture of an operation's activity; and
    - Organize growers' information geo-spatially, tagging information to its related farms/fields;
- An agri-data exchange information and sharing platform that facilitates the Coop's farmer-members sharing data with trusted third parties, with member control over sharing capabilities.

The future vision for GiSC and the AgSimp™ platform solution is to provide additional value back to its members through data analysis as the wealth of information in the system grows.

The Future of Farming: The Opportunity of Digital Ag

From my experiences working with growers and industry leaders, I would say there is much evidence that the clear majority of farmers are not using data in any sort of systematic approach. This concept of utilizing farm data as a real operational toolset has been used in a million slide presentations to say that data-driven decision making is the next ag revolution, and Ag 2.0 (Ag Tech) heading to Ag 3.0 (Internet of Things) will feed the ever-growing world with less arable land. However, nobody has cracked this nut; the opportunity is the grandest of visions, but it has not been proven at any scale.

Ultimately, these circumstances should encourage us, not deter us, in the attempt to get a handle on this huge opportunity. Oh yes, the opportunity is real to utilize data to decrease costs and increase the efficiency of farming practices and make each field, the crop factory, perform to its potential, and we should view the current state of digital utilization on the farm as a blank slate: ripe for deploying the most powerful, yet cost effective, technologies available.

The Future of Farming: The Challenges of Digital Ag

Adoption Issues

I want to take these few moments to cover the topic that I know best: the practical use of agricultural technology in my operation under "in the field" conditions. As a farm operator, I am in the middle of the pack regarding ag technology adoption, putting me in a similar position to most US farmers in the market today. I am always searching for morsels of value: actual uses of technology to solve real problems in my operation. This is tough investigative work when the industry is fixated on the buzzwords of "big data" and "game changing platforms". The truth is "you have to crawl before you walk." For all the "game changing platforms" flooding the market, there is not enough data captured in a useable format to create any real and usable analytics in the industry at any scale, much less the "big data" answers. I think this is shocking to most people that are not inside of the daily operations of a farm.

This is the dirty little secret in this data revolution: an actual shot has not been fired and the adoption of the current data solutions is at best defined as anemic. There has been a rash of "soft-adoption" in the past two years as Ag Tech start-ups offered farmers free chances to try the tools. Evidently however, farmers are for the most part not attracted to "cool tools" or the latest fad. They don't want any tool that takes more time to learn and use than the perceived value any such tool garners. The second part of the problem is the huge data gap from operating in equipment-centric solutions that capture data with equipment, yet doesn't interact effectively with the operator. The operator has many "points of light" in his little black book, and these data points are often not captured in equipment-centric solutions. For example, the seed variety and chemical cocktail used at planting may never be entered to the controller. My guess is the most widely planted variety of corn, as it is labeled in the controller, is just "CORN".

There are a multitude of reasons why this data is not entered into the controller. One of those reasons that should not be discounted is the concern over who else is able to use that data if the data are captured on a piece of equipment with telematics transferring that data directly into a vendor's cloud. Lastly, the real problem is that growers do not see the value in collecting this data, so they do not slow down to put the needed information it in the controller. This is a classic "the chicken or the egg" problem because the value comes from recommendations based on the analysis of good data. The data is not fully collected and most data sets have tremendous gaps in the necessary components to make them valuable without much post collection operations.

I have people say to me that it is impossible to have farmers purchase something they don't know they need. This is a challenge, but I am hopeful that we will see the adoption by growers. There are a couple anecdotes about Texas Instruments (TI) overcoming "adoption" challenges that I love. The first involved transistors. Pat Haggerty, then CEO of TI, realized that if he could create a radio small enough that it be carried on a person, these small radios would become a fad, developing a dynamic market for the transistor radio. He was right, but it was not just size: creating demand for the product meant getting the price point right too. A decade later Pat Haggerty challenged Jack Kilby, a TI lead engineer, to create a market for microchips by using them in "pocket" calculators. Pat wanted them small enough to fit in a shirt pocket and cheap enough to buy on impulse. The rest is history: people, who had previously not realized they needed or wanted such a product, began to buy the calculators. Turns out, almost everyone had a need, and was willing to pay, for the convenience of on the spot addition, subtraction, multiplication, and division. These markets were born out of TI's innovative approach. Not only its approach to technological innovation, but also, and maybe more importantly, its marketing innovations.

We are at a similar place in the ag tech sector. There are obvious adoption challenges to overcome, but the answers are in sight. Solving the adoption dilemma is going to be defined by a product or set of products that solve _real_ farm problems, especially problems which are either time consuming or expensive to solve today, and, much like the TI examples, the solutions must be packaged to attract grower's attention and their price points must be fair and reasonable in the grower's eyes. Secondly, as emphasized above, farm operation data is actually intellectual property and the grower must feel that the service provider has not overstepped in the use of the farmer's data nor violated his privacy rights. The challenges are daunting but I see a bright future for innovation that keeps in mind the value and the trust needed to handle the grower's data.

Time Factors

The challenges that make data collection in agriculture such a difficult task is just the nature of the process. Data collection, if it is done well, is a time-consuming task that must be carried out systematically, but farmers are under constantly changing pressures: prioritizing, and then re-prioritizing the work for the day. Farming is a highly time sensitive occupation. If you were to ask me what differentiates the most profitable farmers from the least profitable farmers, I would say the differentiator is not any one farmer's land, equipment, education, or even technology. The most critical element to thriving in a farming business is "timing".

Timing is everything, and it makes farming a race from start to finish. Timing in land preparation, seeding, fertilization placement, insecticide application, tillage, herbicide application, harvest, and marketing separates farmers into categories of failing, simply surviving, or thriving. Farming is a never-ending battle with the forces of nature and markets, and performing and making decision within these timing windows is difficult. External events outside the grower's control, such as weather, can at times humble the very best farm managers. This year, for me is just such an example: the cotton growing regions around Lubbock have been the most challenging in my 35-year career. Technology has helped me to compensate for the challenging year, but its benefits cannot overcome the forces beyond my control: hail, blowing sand, and other adverse conditions. However, it can help me analyze and diagnose my current situation and help me decide the most opportune direction to move to salvage the year.

The point is a farmer is deciding at any given moment what activity will make the biggest difference, when the year is over, to the bottom line. Effective data analysis from effective data collection will make a difference, but, for farmers, questions remain. Will it make as big a difference as getting this field harvested before an approaching storm system blows down my grain as it is ready to be harvested? Will it make a difference if the approaching rains "string out" my beautiful white field of cotton and lower the quality and then the price? These sort of situations is how gaps in data collection happen and this is one reason why farmers are not going to commit to time-consuming and costly processes, platforms, or services. We are looking for the "biggest bang for the buck" in both real dollars and time invested in the process.

However, I always am reminded of a recent statement of Jeremy Wilson, Technology Specialist at Crop IMS: "At the end of the day you only get one chance to collect data accurately and if you miss it when that machine goes through the field, you cannot get it back." Jeremy is a good friend and a great proponent of precision ag. I know he is right. I also know if we don't collect harvest data in 2017, then the next chance we will have to collect harvest data is another year away. A farmer is going to need to see the real, useable value that can be garnered from this collected data for him to slow down any and do the necessary data collection, accurately and in real-time.

Ag Tech Hype

One of the most significant challenges that is yet to be overcome by any single technology, or integrated technologies, in today's ag tech world is to create a product that: 1) solves a myriad of real pain points in agriculture, and 2) does so at a price point and time utilization metric that is attractive to growers. Both factors are needed to create value. Farmers are hopeful and are waiting, but the reality has not matched the hype. Technology companies, for the most part, have over promised what their "game changing platform" will do for the grower. Farmers, as a result, have become extremely skeptical about

technology and how to incorporate it in their operations. I love a term used by Jason Tatge, CEO of Farmobile. He calls it "Ag-Tech Fatigue". Farmers have tried to see the value in the products offered, but the promises were over blown and using these products often became a leach on the grower's time. In many cases, even if the time consumed to use the product were not excessive, the actual cost of the product would be out of line with a farmer's expectation once the trial period was complete. Lastly, given the amount of time and money are acceptable, the grower may still be uncomfortable with using the product. That discomfort stems from questions regarding who owns the data collected and what rights technology providers have to use the data. At the end of the day this is the value proposition I am trying to find: I want to pay a fair and reasonable price for a product that delivers real information for making decisions on my farm in a timely manner and without the fear of my data being used by others without my express permission or in a way that may be ultimately detrimental to my farm or my neighbor's farms.

Ownership Concerns

GiSC is trying to understand this complex world of data and its use. The issue is complicated, and one problem is that one size does not fit all. Deciding on a piece of data collecting equipment, based on its capabilities and features, is challenging enough, much less without the challenge involved in understanding the legalese. The fine print in an end user license agreement (EULA) regarding my data is very complex. The various EULAs used in the market are so different and diverse that I could not even do justice to the discussion. In some instances, I own the raw data until it is on the provider's servers, but then once the data is stored on those servers, it becomes the provider's data. The provider, in many cases, will promise to never disclose my identity via a process known as anonymization. In many cases these EULAs will include phrases such as: "the grower grants (the service provider) a perpetual worldwide license to the use of any data stored in the system."

GiSC is trying to understand what all this means. Let me be plain when I say that we may need to decide if we, as growers, can accept these EULAs, and the treatment of our data under them, as they are typically structured today. I have tried to hold to an altruist view of what a farmer's rights are in respect to data, but we may need to further investigate if there is potential value by coming to a new conclusion. GiSC and its grower members must decide the data model that brings the most value to the grower's bottom line and is the least disruptive to our world and our trusted partners.

Disruption Concerns

Another challenge facing farmers and the ag tech space are the new players with little understanding of the grower's ecosystem and his network of advisors. An often overused term among technology start-ups is industry disruption. Technology focused magazines and journals are filled with examples of new companies with game changing platforms that are destined to disrupt entire industries. Disruption is a common theme in tech start-up pitch decks shown to investors as the start-ups seek funding. In the ag tech space, claims such as this or that start-up is going to be the "Amazon of Agriculture". This sounds great to investors, but in truth, most great ideas did not uproot an industry to gain a foot hold. The "old guard" are not the farmer's enemies; they are his support system: the seed dealer, fertilizer dealer, crop insurance agent, banker, equipment salesman, agronomist, entomologist, etcetera. This list represents people that the farmer knows on a personal level and contribute to farm's profitability. When problems arise on the farm, farmers can call their agronomist at 10 pm or 6 am, and he will take their call. Farmers, and the businesses that serve them, are intertwined in a sonnet to produce a crop in a timely

manner and at a cost that has them back next year to make new purchases from the vendor. Therefore, we must be cautious when we make blanket, reflexive statements, calling disruption "good". Peter Thiel, PayPal founder and venture capitalist offers this advice in his book "Zero to One":

> "Silicon Valley has become obsessed with 'disruption.' Originally, 'disruption' was a term of art to describe how a firm can use new technology to introduce a low-end product at low prices, improve the product over time, and eventually overtake even the premium products offered by incumbent companies using older technology…. However, disruption has recently transmogrified into a self-congratulatory buzzword for anything posing as trendy and new…. But if you truly want to make something new, the act of creation is far more important than the old industries that might not like what you create. Indeed, if your company can be summed up by its opposition to already existing firms, it can't be completely new…."

Industry Fears

I am borrowing this often-said phrase from others because it is true: "Ag is a small room, but I would not want to paint it." I proceed with caution here, even though a part of me would like to hit "reset" and start over with ag digital technology, including data creation, data collection, data storage, and data analyzation. GiSC has tried to work closely with crop protection companies, input providers, and others with growers as customers, growers who would benefit from utilizing their data and aggregated data, improving those operations through benchmarking and other analytical tools.

I have frankly been confounded by the fact that many, if not most, of these trusted partners of growers are not very open to the idea of their customers integrating the data captured and created via services offered by those trusted partners with other data related to the grower's operation, much less integrating that data in anonymized, aggregated data sets of multiple growers. In fact, many such services require the data captured/created from the service be stored within the service provider's system and only be utilized with the particular service provider's tools. The Ag Tech world is littered with those that live in fear of what a farmer might be able to do with better data. Therefore, most try to create a standalone data ecosystem, in which the farmer's data is stored for post-season analysis and creating next year's recommendations. This creates the "data silos" mentioned earlier. That data is never benchmarked against anything, and therefore, the potentially most significant value of such data derived from groups of farmers working together never materializes. In my opinion, if current farm groups don't find a way to move beyond this fear, then Silicon Valley will eventually have a heyday in the ag world, and the disruptions I cautioned against above, will become reality.

Rural Broadband and Connectivity

The last challenge I need to mention involves the continuing need to address the inadequate communications infrastructure in rural areas. While population continues to become more concentrated in the most urban, populated areas, the simple fact remains that those populations' food and fiber continue to be supplied by farms in rural America. The dirt cannot move to town, and we need the means to move the data captured, created, and collected on the farm to "clouds", where the proper analysis can be performed. The rural communications initiatives in the US need to be strengthened if we are going to be part of feeding the world.

I would encourage Congress to continue, and even increase, support of FCC's initiatives including Connect America Fund and Mobility Fund. I understand that serving rural areas requires higher costs,

but those costs pale in comparison to the cost of failing to assure adequate communications in rural areas, the price of which is the inability to meet the objective of feeding the world. The current trajectory of total-factor productivity gains in agriculture is inadequate to fill the gap between food production capacity and demand. According to knowledgeable sources, the current gap implies starvation of at least 500M people by 2050, an alarming and totally unacceptable figure. Precision Agriculture advances and other technologies are required to fill that gap, but without new generations of fixed and mobile communications services in the rural areas that produce that food, those productivity gains will not be possible. We must have fast broadband available in rural homes and offices and wireless broadband at the field level with the capability of moving information to and from the cloud for processing, analytics and better decision making.

There is great potential for innovation and entrepreneurship in rural America (Ag and other) but it requires fast internet connections and 4G wireless services – the same tools that nourish entrepreneurship in metro areas. I make a plea that we cannot afford to deny our potential entrepreneurs and farmers the tools required to assure the maximum contribution to our economy.

Challenges of Digital Ag – Rabobank Summary

I would like to conclude addressing the challenges of digital ag with a profound synopsis of the issue made by Rabobank Senior Research Analyst Kenneth Zuckerberg. In May 2017 Rabobank's RaboResearch issued a report titled "Bungle in the Ag Tech Jungle, Cracking the Code on Precision Farming and Digital Agriculture." The full report is attached as an addendum to this written testimony with the permission of Rabobank Mr. Zuckerberg's summary is as follows:

> "Agriculture has, over the course of its history, embraced new technologies that improve productivity. 'Digital agriculture' represents the latest wave of sector innovation-and while it offers many promising new technologies, farmer adoption has remained quite modest. The consensus view is that growers will not invest in new/unproven technologies during a cyclical downturn, but there seems to be a bigger limiting factor at work here. This nascent industry has been trying to attract customers before the ecosystem has been properly constructed. What we believe is missing is a standardized way to gather and interpret data, and then translate actionable insights to commercial users-insights which then, in turn, can deliver value to growers. We believe that a standardized system is necessary to drive farmer adoption of digital agriculture services … Yet without a common data platform and operating system, it is unlikely that growers, or the vendors providing precision farming services, will fully capture the value associated with digital agriculture."

The Future of Farming: Innovation and Excitement

I can complain every day about all the things that are wrong in the space, but that does not create what I need in my farm operation. The point is that even with problems that seem at times overwhelming, there are nuggets of gold; I find these nuggets all the time as I meet passionate founders of ag tech companies, pioneers who are trying to make a difference. They certainly are capitalist: they want to bring value to the grower and get paid for the value. I am also encouraged by ag groups such as AgGateway and the Open Ag Data Alliance (OADA) who are working to overcome the digital challenges growers face, and am especially encouraged as the ADC and GiSC continue working on behalf of the grower as a vanguard, allowing growers to focus on what they do best – producing a crop.

Innovation is the engine of ever increasing agricultural productivity. As the founder of GiSC, I have the pleasure of seeing innovation happen in exciting new places. On my operation, I have tested many innovative products such as Farmobile's Passive Uplink Connection (PUC), which lets you collect data and seamlessly move it to a cloud regardless of the color of your equipment. For instance, just last week at my farm Blue River Technology tested its "See & Spray" technology, which utilizes computer vision and artificial intelligence to treat weed problems in the field. I see innovation from major technology companies. IBM, as an example, is recruiting and employing highly competent people with expertise in the agriculture industry and has developed powerful weather analytics that can be integrated into digital platforms. Major cellular service providers are also working on applications that leverage their networks to deliver digital tools to growers.

Lastly, without a doubt, innovation is about to take "front and center" stage around the Internet of Things (IoT), as data collection in ag becomes almost automatic. The handheld computer we all carry around, the smartphone, enabled by IoT sensors on the farm, will provide a leap in the data acquisition landscape. The day of a farmer spending a couple of hours at the end of the day entering data will be a thing of the past; data capture and acquisition will just "happen" as we go about our daily business as farm operators. I am thankful to be seeing the beginning of Ag 3.0, and I would suggest you all stay tuned, because "you ain't seen nothing yet".

Last Words:

Somewhere, somehow, in this complex vast world of data utilization, an ecosystem will get built that will overcome the digital ag challenges: the value challenge, the time/resource constraints, and the trepidations of both growers and their trusted partners. Ultimately, this digital ecosystem must be grower-centric and provide for the exchange of information and knowledge, a world where information is not in "data silos" but is available to growers and growers' trusted advisors.

Thank you for the opportunity to speak to you about a topic that I am very passionate. I believe unless we, as farmers, have "stock" in the data we create, in the next decade our world will completely change, or be lost completely. GiSC is a proponent Section 1619 of the 2008 Farm Bill. We are not asking you to make it easier for others to access our USDA information. We appreciate that you understand that there is a right to privacy in our farm locations and our CLUs. Therefore, it would be beneficial to continue to guard the CLU (Common Land Unit) to protect the privacy of America's farmers. Please continue to be supportive of more digital solutions at FSA/RMA, including automating data delivery from USDA to the grower. GiSC is a willing partner in the task, and we will continue to work hand in glove with FSA to try and understand how to keep the grower in control of this digital world. Lastly, thank you for all the hard work you do for the American Farmer.

Addendum to:

Statement of Billy Tiller
Before the Subcommittee on General Farm Commodities
And Risk Management Committee on Agriculture
U.S. House of Representatives
Washington, D.C. – July 13, 2017

- <u>Attached</u>: RaboResearch Report May 2017, "Bungle in the Ag Tech Jungle"

Bungle in the Ag Tech Jungle

Cracking the Code on Precision Farming and Digital Agriculture

Kenneth S. Zuckerberg
Senior Research Analyst
+1 212 916 7998

Dirk Jan Kennes
Global Sector Strategist
+852 21032423

Contents

Summary

Agriculture has, over the course of its history, embraced new technologies that improve productivity. 'Digital agriculture' represents the latest wave of sector innovation—and while it offers many promising new technologies, farmer adoption has remained quite modest. The consensus view is that growers will not invest in new/unproven technologies during a cyclical downturn, but there seems to be a bigger limiting factor at work here. This nascent industry has been trying to attract customers before the ecosystem has been properly constructed. What we believe is missing is a standardized way to gather and interpret data, and then translate actionable insights to commercial users—insights which then, in turn, can deliver value to growers. We believe that a standardized system is necessary to drive farmer adoption of digital agriculture services—and within this report, we offer our take on how digital agriculture can add value to production agriculture. Yet without a common data platform and operating system, it is unlikely that growers, or the vendors providing precision farming services, will fully capture the value associated with digital agriculture.

Agricultural Innovation

The Four Waves

The complex process of crop and livestock farming has evolved over the course of thousands of years, and digital agriculture is simply the latest wave of innovation. Advances in farming have historically followed the growth and prosperity of civilization, with mechanization playing an especially prominent role throughout history. The invention of the horse-drawn seed drill in 1700 by Englishman Jethro Tull was notable in that it allowed farmers to plant crops in rows more efficiently than could be done by hand.

Several other useful farm machinery innovations came after the seed drill, namely the cotton gin, reaper/binder, combined harvester-thresher, and gasoline-powered tractor. Collectively, these advances in machine technology fall into a category that we call the first wave of agricultural innovation.

A second wave began in the 1940s, as chemicals used during the war years were repurposed for use in production agriculture. The associated yield benefits of applying nitrogen fertilizer and pesticides incentivized many U.S. farmers to focus on growing few types of crops, but on a much larger scale, abandoning the tradition of farming both crops and livestock. This wave also marked the birth of new farming practices—termed the 'green revolution'—that helped improve crop productivity through more effective usage of synthetic fertilizers and crop production chemicals, as well as field irrigation.

A third innovation wave started in the 1980s and 1990s, a period considered to be the birth of 'precision farming,' a precise sustainability-oriented approach to farming that sought to produce more with fewer inputs and lower environmental impact. The third wave also included gains in plant breeding through genetic engineering and controlled pollination, genetics-based animal breeding, the use of global positioning systems (GPS) on tractors, as well as remote sensing technologies utilizing satellites, drones, and other UAVs.

Digital agriculture is the fourth, and latest, wave of agricultural innovation—and one that has been largely funded by venture capital (VC) investors, along with the VC units of several major F&A and equipment companies. Since the beginning of 2014, over USD 6.5bn of capital has been invested in new precision farming and data-oriented technologies seeking to modernize farming for the digital age. These technologies have taken many shapes, forms, and sizes. These range from cloud-based software tools to hybrid hardware/software products that are 'smart' in that they can communicate with other connected devices wirelessly and digitally, with minimal human intervention.

Table 1: The Four Waves of Agricultural Innovation

Wave	Description
First wave	Mechanization (seed drill, cotton gin, reaper/binder, combined harvester-thresher, tractor)
Second wave	Ag chemistry (nitrogen fertilizer, pesticides)
Third wave	Precision farming (biology, plant and animal genetics, GPS)
Fourth wave	Digital agriculture (smart hardware, analysis of temporal layers of spatial data, weather, and remote sensing to evaluate crop conditions)

Source: Food and Agricultural Organization of the United Nations, USDA, Rabobank 2017

Another dimension of smart farming involves algorithms, artificial intelligence (AI), and machine learning, which, in essence, combines mathematics, data analytics, and predictive modeling to produce customized recommendations designed to help growers farm more efficiently, sustainably, and profitably.

Figure 1: Investments in Ag Technology (excluding food e-commerce), Q1 2014-Q4 2016
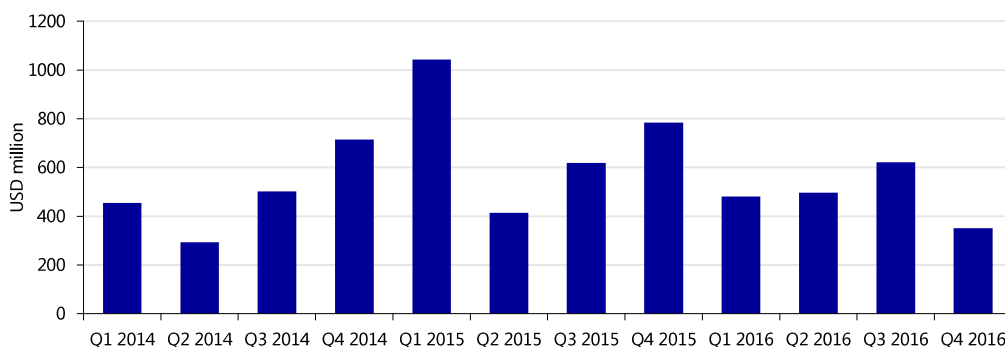
Source: AgFunder AgTech Investing Report (Year in Review 2016) 2017

These customized recommendations are intended to be precise and prescriptive (building upon the original tenants of precision farming) in that they provide specific advice for managing critical tasks that occur throughout the growing/production season. For crop farmers, the prescriptions conceptually include instructions on what to plant, where and when to plant, what to apply to the

soil and the plant (in the form of water, nutrients, and crop protection chemicals), how to most efficiently apply those inputs (e.g. on a variable rate basis), and when to harvest. For dairy and livestock farmers, the prescriptions offer direct guidance on when to feed the animal, provide vitamins and/or medicine, guidance on when to milk and/or when to slaughter, and other herd management matters.

The Promised Value

Digital agriculture offers the promise of greater income and lower volatility, utilizing data, mathematics, and logic to add value to farm decisions by removing human emotion and bias. In crop farming, the 'promised value' for growers consists of optimal financial risk-adjusted returns on the capital used to farm. The idea here being that improved agronomic practices, coupled with more precise field decisions (e.g. the timing and type of nutrient applications) tailored to local field and intra-field conditions, can create the promised value through higher crop yields and lower input costs (for example, lower and more precise nutrient and ag chemical applications), as well as operational efficiencies and time management (automatic, rather than manual collection of helpful data to drive decisions can allow farmers to complete tasks which cannot be automated). Another consideration is better grain quality and consistency, which results in additional value to midstream and downstream buyers.

Below is a partial list of precision and digital technologies currently in use in the global farming community.

Table 2: Leading Precision and Digital Technologies

Auto-steering and guidance systems	*Remote sensing (drones, UAVs)*
Farm data management software	*Satellite imagery (high-resolution)*
Crop sensing/measurement	*Variable rate technologies*
Global positioning systems (GPS)	*Yield monitors*
Milking robots	*Yield maps*
Precision irrigation & water usage monitoring	*Wireless weather stations*

Source: Rabobank 2017

Barriers to Adoption

Despite the strong conceptual foundation for using data-intensive tools in agriculture, farmer adoption has been quite low. While there are numerous reasons for this, we highlight five reasons that have been validated in our field research over the past three years with growers and data scientists:

- **First, many new software technologies lack a clearly articulated value proposition** and, in fact, are not 'proven' in terms of demonstrating a calculated return or payback on investment. This contrasts with the situation that occurs when new seed technologies come to market, a process in which field trials over multiple growing seasons culminate in a proof of concept, helping to ensure customer trust and subsequent product adoption. Furthermore, we have observed that certain start-up companies and investors have an imperfect understanding of telemetry, artificial intelligence (AI), and data analytics. For example, just because a piece of equipment used in farming is SMART—it can collect data and transmit data—such data must be further analyzed before it can be translated into an actionable insight.

- **Second, many farms actually lack the necessary technological infrastructure** (enterprise-grade business computing networks, with proper/secure cloud storage and backup), beyond the missing proof of concept, required to interact digitally with industry farm management software

systems offered by vendors such as Conservis, Farmers Business Network, Granular, or SST. Trying to get farmers to purchase both IT hardware and software is hard enough in a favorable commodity price environment, as farmers are typically resistant to change, given the 'family tradition' and experience-based nature of farming. Trying to do this during a downturn in the crop cycle (which the industry has been experiencing since commodity prices and farmer income peaked in 2012/13) is, and has been, nearly impossible.

- **Third, selling software as a service (SaaS) to financially strapped farm customers has been a very difficult revenue generation strategy**, given these dynamics. Perhaps a better strategy could be to provide growers basic software without charge, to encourage use and adoption, while selling premium add-on products and services to independent agronomists and crop consultants who advise the growers.

- **Fourth, data ownership and privacy has been a heated, widely debated topic** ever since big data entered the global farming conversation. The matter is actually part of a larger consumer privacy conversation involving medical records, web browsing activities, and the resale of consumer data for use in marketing. An innovative idea to ensure greater privacy is creation of a farmer not-for-profit data cooperative, owned or operated by growers or by an unbiased third party such as an agricultural university. The industry has already seen examples of these ideas in the form of Grower Information Services Cooperative (GiSC) and Ohio State University's Agricultural Data Corporative in the United States. Similar ideas have gained traction in Europe, especially the Netherlands, among both farmer cooperatives, as well as other groups, with a notable example being the Farm-Oriented Open Data in Europe (FOODIE) project in Spain, the Czech Republic, and Germany.

- **Fifth, digital agriculture lacks a universal operating platform** in which to connect the entire ecosystem. At present, digital farming lacks a standardized operating system and/or data platform in which the value chain can upload, store, validate, refine, cleanse, and analyze data and in which relevant stakeholders can easily communicate with each other. Based on our research interviews with data scientists from various enterprise software and business analytics firms—including EMC, IBM, and Verisk—we believe that a data warehouse and data analytics structure (which connects all stakeholders: farmers, software vendors, equipment manufacturers, and data analytics companies, and can enable data sharing) is critical for digital agriculture to add value.

A Framework for Adding Value

Creation of a universal data platform is critical. However, going from the 'concept' stage to the 'blueprint' stage is a complicated exercise. How this happens and who pays for it will depend on which party/parties take leadership in organizing and aligning the industry, and how much capital is set aside for building, testing, and maintaining required systems. Although it took two decades for electronic commerce to evolve after internet access became available to the general public, we would expect creation of the necessary platforms for digital agriculture to occur much faster.

The Future of Digital Farming

Rabobank

DATA WAREHOUSE & VAULT

A trusted, secure storage container for historical production results and farm practice data. After raw data is gathered, it is then curated (i.e. formulated) for data analysis by outside vendors. These vendors presumably access the data via paid subscription only if and when authorized by growers

VENDOR DATA ANALYTICS PLATFORM

Vendors consist of farm input providers, retailers, distributors, and other service providers seeking to extract actionable insights from the data warehouse & vault to 'commercial users.' The commercial users can then incorporate the insights into the advice and services they deliver to growers

Actionable Insights

Agronomic Science / Operational Advice

Financial / Capital Management Advice

Uploaded via Cloud Computing Interface

Aggregated Data

Farm Management Software

Smart Devices (Internet of Things, or IoT)

Remote Sensing & Machine Data

Commercial Users

Agronomists
Farm Consultants
Professional Farm Companies
Midstream Players (ABCDs)
Brand Owners (Food Companies)
and their supply chains

FARMERS

Margin-Enhancing Recommendations

The Five Components of Precision Farming

1 Precision Soil Preparation

2 Precision Seed / Planting

3 Precision Crop Management

4 Precision Harvesting / Processing

5 Precision Livestock Farming

Source: CEMA 2017

Concluding Thoughts

Digital agriculture represents the newest—and perhaps the most promising—wave of industry innovation that, in our opinion, can help production agriculture operate more efficiently and sustainably, both in terms of long-term financial success and continued environmental stewardship.

While this report approaches the subject of digital agriculture largely from the perspective of upstream farming (crop and livestock) and farm inputs (seeds, crop protection chemicals, fertilizer, and machinery) companies, a common operating system for data gathering, collaboration, and analytics is of critical importance to other players along the value chain.

Midstream food companies and their supply chains (such as processors, storage, and transportation companies) are increasingly demanding more data and information. This is largely driven by the end consumer who demands greater transparency about the origin of commercially sold food. In our opinion, consumer sentiment and regulations governing the interest of consumers will ultimately guide the further evolution and adoption of digital agriculture.

Imprint

Kenneth S. Zuckerberg	Senior Research Analyst	kenneth.zuckerberg@rabobank.com
		+1 212 916 7998
Dirk Jan Kennes	Global Sector Strategist	dirk.jan.kennes@rabobank.com
		+852 21032423